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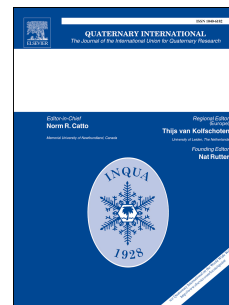
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Title: Dating the funerary use of caves in Liguria (northwestern Italy) from the Neolithic to historic times: results from a large-scale AMS campaign on human skeletal series.

Authors: Sparacello VS¹, Varalli A², Rossi S³, Panelli C^{4,5}, Goude G⁶, Palstra SWL⁷, Conventi M⁸, Del Lucchese A⁸, Arobba D⁹, De Pascale A⁹, Zavattaro M¹⁰, Garibaldi P¹¹, Rossi G¹¹, Molinari I¹¹, Maggi R¹², Moggi-Cecchi J¹³, Starnini E¹⁴, Biagi P¹⁵, Dori I^{1, 13, 16}.

Affiliations

¹ Univ. Bordeaux, CNRS, PACEA, UMR 5199, 33616 Pessac, France

² Department of Archaeology, Durham University, UK

³ Soprintendenza Archeologia, Belle Arti e Paesaggio per le province di Como, Lecco, Monza e Brianza, Pavia, Sondrio e Varese, Milano, Italy

⁴ CEPAM, UMR 7264 CNRS, Université Côte d'Azur, France

⁵ Museo Civico Archeologico di Remedello, Remedello (BS), Italy

⁶ Aix Marseille Univ, CNRS, Minist Culture, LAMPEA, Aix-en-Provence, France

⁷ Centre for Isotope Research, ESRIG, University of Groningen, The Netherlands

⁸ Soprintendenza Archeologia, Belle Arti e Paesaggio per la città metropolitana di Genova e le province di Imperia, La Spezia e Savona, Italy

⁹ Museo Archeologico del Finale, Finale Ligure, Italy

¹⁰ Museo di Storia Naturale, Sezione di Antropologia e Etnologia, Università degli Studi di Firenze, Italy

¹¹ Museo di Archeologia Ligure, Genova Pegli, Italy

¹² L.A.S.A. (Laboratorio di Archeologia e Storia Ambientale), Università di Genova, Italy

¹³ Dipartimento di Biologia, Università degli Studi di Firenze, Italy

¹⁴ Dipartimento di Civiltà e Forme del Sapere, Università di Pisa, Italy

¹⁵ Dipartimento di Studi sull'Asia e sull'Africa Mediterranea, Università Ca' Foscari di Venezia, Italy

¹⁶ Soprintendenza Archeologia, Belle Arti e Paesaggio per le province di Verona, Rovigo e Vicenza, Italy

Abstract

The multidisciplinary research team of this new project aimed at the chronological, anthropological and funerary behavior characterization of the skeletal remains unearthed from various caves in western Liguria (northwestern Italy) between the mid-1800s and the 1990s. Most of the burials and scattered bone assemblages were excavated prior to the development of modern stratigraphic methods, or come from disturbed contexts, often resulting in a vague chrono-cultural attribution. We present here the results of a systematic dating project that produced 130 new AMS dates on human bone samples (documented burials or individuals from scattered remains) from sixteen Ligurian caves, including most of the skeletal series from renowned sites such as Arene Candide Cave and Grotta Pollera.

Results highlighted the funerary use of these caves from the last quarter of the sixth millennium BCE to the Common Era, with the majority of results clustering in the first half of the fifth millennium BCE. These dates allow for an initial assessment of patterns in Neolithic mortuary use of Ligurian caves, and aided in particular the characterization of funerary practices during the Square Mouthed Pottery culture.

Keywords: Neolithisation, Radiocarbon dating, Copper Age, Bronze Age, Iron Age, Byzantine Period, mortuary behaviors

1. Introduction

Few regions in the Mediterranean show a concentration of prehistoric funerary sites from the Upper Paleolithic, Neolithic, and Metal Ages like western Liguria (*“Liguria di Ponente”*), where hundreds of karstic caves open in a radius of a few kilometers around the Finale Ligure (*“Finalese”*) and nearby municipalities (Brandolini et al., 2011). The history of archaeological and anthropological research in this area begun in the mid-1800s, at the dawn of the modern conceptualization of those disciplines. In the early decades, numerous naturalists, geologists, amateurs and looters explored the archaeological deposits of most caves, followed by more modern excavations beginning in the 1930s and 1940s (De Pascale, 2007, 2008, 2014, 2018; Formicola and Holt, 2015; Maggi, 1997a; Rossi et al., 2014). A survey of the literature and excavation reports indicates that, from the late 1800s to the 1990s, up to 200 burials and a myriad of scattered human remains possibly belonging to the Neolithic were excavated from several caves (e.g. Arene Candide, Pollera, Arma dell’Aquila, Bergeggi, and many others, see below), making the Ligurian skeletal series one of the most important for the understanding of the cultural and biological dynamics of the Neolithisation of the western Mediterranean (e.g. Arobba et al., 2017; Bernabò Brea, 1950; Biagi and Starnini, 2016; Binder, 2013; Binder and Sénépart, 2010; Branch et al., 2014).

Unfortunately, the methodology used to record earlier findings was far from the standards used today, and the resulting documentation, when present, is often lacking or fragmentary (e.g. De Pascale and Maggi, 2015; Issel, 1893, 1908; Richard, 1942; Sparacello et al., 2018a, b, 2019). The skeletal collections were often part of private collections, and are currently housed in various museums in Italy, but in part were lost or transferred abroad (Almagro, 1955, 1957; Moggi Cecchi, 2014; Panelli and Rossi, 2015, 2017). As a result, the first significant attempt to create a complete catalogue of the Neolithic Ligurian anthropological material (Parenti and Messeri, 1962) already acknowledges the unknown fate or uncertain composition of some of the skeletal collections. In addition, following the bias of anthropologists of the time, the catalogue focused on complete burials of adults, only briefly and partially reporting on juveniles and on the composition of disarticulated remains. Subsequent attempts to provide a complete overview of prehistoric burials in Liguria could not overcome these limitations (Delfino, 1981).

Furthermore, the chrono-cultural attribution to the Neolithic of most of the human remains was tentative and generic (Parenti and Messeri, 1962). Human communities used Ligurian caves for various activities and funerary purposes throughout prehistory, from the Upper Paleolithic to the Roman Age, but especially during the Neolithic, as suggested by the stratigraphy and archaeological assemblages unearthed at Arene Candide Cave (e.g. Arobba et al., 2017; Bernabò Brea, 1946, 1956; Maggi, 1997b; Tiné, 1999). In absence of more than vague information about the context, as is the case for several partial skeletons and scattered remains, human remains may in fact date back to any of these phases of occupation.

In addition, “Neolithic” comprises a succession of different cultural traditions. The western spread of the Neolithic from the Near East reached southern Italy c. 6000-5800 BCE, and by 5800-5600 BCE people belonging to the Impresso-Cardial cultural complex (ICC) were settled in the Liguro-Provençal Arc (Binder et al., 2017). Beginning c. 5000 BCE, the Square Mouthed Pottery culture spread in Liguria and in northern Italy during the fifth millennium BCE (SMP; c. 5000-4300 BCE; Barfield, 1972; Binder and Sénépart, 2010; Del Lucchese and Starnini, 2015; Maggi, 1997a; Pearce, 2013). Later, Liguria was the gateway for the diffusion of the *Chasséen* in northern Italy from France (c. 4300-3700 BCE) (Bagolini and Biagi, 1990; Barfield, 1972; Binder et al., 2008; Crepaldi, 2001; Maggi, 1997a). Most burials unearthed during early excavations were labelled as likely/probably/possibly “Neolithic”, or as belonging to the SMP culture, depending on the information available about associated artefacts, and on stratigraphy when available (e.g. Canci et al., 1999; Del Lucchese, 1997; Formicola, 1986). In addition, several burials firmly associated to SMP layers present a funerary structure composed by a cist of stone slabs, with the individual laid down crouched on the left side (Del Lucchese, 1997). Therefore, information on body position, and on the presence/absence of the stone cist, allowed for a dubitative chronological attribution of some additional burials from early excavations.

Scattered human remains were generally attributed to collective burials (“*grotticelle sepolcrali*”) that seem to characterize the mortuary behavior from the Copper (c. 3600-2200 BCE) and Early Bronze Age (2200-1600 BCE) (e.g. Bagolini and Biagi, 1990; de Marinis, 2013; de Marinis and Spadea, 2004, 2007; Del Lucchese and Maggi, 1998; Delfino, 1981; Maggi and Pearce, 2013; Parenti and Messeri, 1962). In some cases, this was confirmed by directly dated human remains found in association with material culture from the early Bronze Age (Del Lucchese and Maggi,

1998: 36). Still, a large number of skeletons and partial skeletons had no surviving information on funerary treatment, or were buried in a simple pit without grave goods, especially children (Bernabò Brea, 1946: 18-22; Del Lucchese, 1997). It was often impossible to determine whether scattered remains resulted from disturbed burials, rather than belonging to collective inhumations from later periods.

Despite these uncertainties, and probably due to the poor quality of the historic documentation, until recently few human remains were directly dated, mostly coming from Arene Candide Cave (Table 1). Among these, three have an uncertainty too high to improve their generic attribution to the Neolithic (GX-16931-A, GX-16963-G and GX-16962-G), and are virtually unusable, while the dates obtained for other two individuals do not seem to fit with the stratigraphic relationships at the site. Two dates for Arene Candide V (KIA-28340; Le Bras-Goude et al., 2006; Beta-109797) from Bernabò Brea and Cardini excavations (1940-50) place this burial within the mid-sixth millennium BCE, but the stone cist in which the body is buried – thought to be typical of the SMP Neolithic – covers another cist belonging to individual VI, directly dated to 4360-3780 BCE (Table 1; Del Lucchese, 1997, p. 607; Maggi, 1997b, p. 36). The individual 2 from Tiné excavations, buried in a simple pit and covered with ochre, had been attributed to early Neolithic based on funerary behavior and stratigraphy (Canci et al., 1999; Tiné, 1976, 1986), but the direct date placed it at the end of the fifth millennium BCE (Biagi and Starnini, 2016). More recently, one child from Grotta Pollera was dated to the mid-fifth millennium BCE (Sparacello et al., 2017), and a number of AMS dates on human bone from Arma dell'Aquila highlighted the presence of burials and scattered human remains belonging to the sixth millennium BCE, contemporary with the ICC in Liguria (Mannino et al., 2018; Sparacello et al., 2018b, 2019; Table 1).

1.1. Purpose of the study

The gap in knowledge regarding the effective number and biological profile of skeletal remains, their precise chronology, and funerary context, has constantly prevented anthropologists from providing more than general insights on “Neolithic” lifestyle (funerary practices, activity patterns, diet, dental and skeletal variation, pathology) sampling from a larger, probably heterogeneous, pool (e.g. Canci and Dini, 2003; Formicola, 1987; Formicola et al., 1987; Goude et al., 2014; Le Bras-Goude et al., 2006; Marchi et al., 2006, 2011; Sparacello and Marchi, 2008;

Sparacello et al., 2014). In order to investigate questions on Neolithic biocultural adaptive strategies, in a diachronic framework linking material culture with funerary behaviors and biological traits, it was paramount to improve the chronological characterization of the Ligurian Neolithic skeletal series.

To begin overcoming these limitations, the authors of this study were involved in two projects: “Burial practices at the Pleistocene-Holocene transition: the changing role of pathology, violence, and exceptional events (BUR.P.P.H.; PI VSS)”, and “Dental anthropology at the Pleistocene-Holocene transition – insights on lifestyle and funerary behavior from Neolithic Liguria (Italy) (DEN.P.H.; PI ID)”. The joint project (BUR.DEN.), in collaboration with Museums and officers of the Italian Ministry of Cultural Heritage (see acknowledgements), has reexamined and catalogued the entire extant skeletal series, and collected comprehensive information on its biology (sex, age, pathology, osteometric and non-metric traits, dental anthropology), biochemical characterization (CNS stable isotopes), and information on the archaeological and funerary context when available.

In addition, the project undertook – to our knowledge for the first time in an Italian skeletal series of this size – a systematic, and as much as possible complete, campaign of direct radiocarbon dating of the human remains. We present here the results of 130 new AMS radiocarbon dates on human remain samples (from burials, individuals reconstructed from disturbed and/or undocumented contexts, and isolated scattered remains) aimed at an initial assessment of the chronology, possible temporal clustering, and chrono-cultural attribution of the skeletal series from western Liguria. The results will also set the bases for several anthropological studies on paleodemography and paleoepidemiology, diachronic changes in diet, habitual activities, life history, and funerary behaviors.

2. Materials and methods

The BUR.DEN. catalogued and studied skeletal remains from 16 western Ligurian caves/rock shelters in the Finalese area and from two caves in the nearby Val Pennavaira (Figure 1), unearthed during excavations from the late 1800s to the 1990s (Table 1). These skeletal remains constitute the vast majority of the “historical” skeletal series unearthed in the area (Parenti and Messeri, 1962), and are curated in four Italian museums (Museo Archeologico del Finale, Finale Ligure; Museo di Archeologia Ligure, Genova Pegli; Museo di Storia Naturale dell’Università di

Firenze – sezione di Antropologia ed Etnologia, Firenze; Museo Navale Romano, Albenga; Supplementary Information Table S1).

A detailed catalogue of the osteological composition of each skeletal assemblage goes beyond the scope of this paper, and will be included in further publications (cf. Sparacello et al., 2018a, 2018b, 2019). In this study, we report whether the date was performed on bone belonging to three categories: “burial”, “disarticulated/partial skeleton” and “scattered remain” (Table 1). The category “burial” comprised individuals for which information (of varying quality) on the depositional context is available and reasonably reliable. The category “disarticulated/partial skeleton” includes individuals – especially from earlier excavations – for which the attribution to a specific burial described in the excavation diaries is more tentative. The category “scattered remains” is composed by specimens from fragmentary and commingled contexts, for which we attempted to sample fragments from elements belonging to different individuals.

Table 1 and Figure 1 about here

The 130 AMS measurement were performed on 120 individuals/isolated remains, which were sampled for both AMS dating and isotopic analysis (Goude et al., in review, and in preparation); therefore, rib fragments, which are ideal for isotopic analysis, were preferred when available in burials and partial skeletons (details in Supplementary Information Table S1). The study of CN stable isotope ratios for each sample allows for the detection of individuals that consumed significant amount of marine resources, and, in case, correct the radiocarbon date accordingly (Fontugne et al., 2014). However, none of the individuals in this study required such correction.

Several individuals in the skeletal series were restored and consolidated using glues and plaster, and often a coating of consolidant originating from organic matter was applied. This coating is water soluble, and easily removed by ultrasonic bath. Previous studies have demonstrated that, with a careful pre-treatment of the samples, the isotopic data is not affected by the presence of this modern collagen in the great majority of cases (Goude et al., 2011). However, the possible effect on radiocarbon dating is unknown. We tested the consistency of the results by dating, on the same individual (Pollera 1 excavation Issel-Morelli 1892), a rib coated with consolidant and the dentine from an unworn molar, which was certainly not contaminated. The invasive nature of this procedure did not allow to perform this test on a larger sample.

The bone collagen used for both elemental composition analysis and radiocarbon dates was extracted at the LAMPEA (UMR 7269, Aix-en-Provence), according to the laboratory standard protocols. ^{14}C measurements on the collagen samples pretreated by LAMPEA were performed at the Center for Isotope Research (CIO) in Groningen (the Netherlands; $n = 114$; Aerts-Bijma et al., in preparation), and the Artemis AMS facility in Saclay (France; $n = 16$; Moreau et al., 2013). Laboratory protocols and procedures are detailed in Supplementary Information 1.

For all dates, calendar ages were determined using OxCal v 4.3 (Bronk Ramsey, 2009) and calibrated using IntCal13 curve (Reimer et al., 2013). Reported calibrated age ranges correspond to 95.4% probability.

3. Results

Results of the direct dating are reported in the Appendix 1 at the end of this paper. In order to identify the specimens, we used an individual identifier based on the museum catalogues and on notes accompanying the material, but also an individual code created by the BUR.DEN. project (Appendix 1). A more detailed version of the Appendix 1 is available as Supplementary Information (Table S1), which reports the sample number, the type of skeletal element analyzed, and information on collagen preservation. The table also reports the six samples, in addition to the 130 reported here, for which collagen extraction failed.

The two dates performed on the same individual (Pollera 1 excavation Issel-Morelli 1892) to check for the possible influence of consolidant on radiocarbon determination are GrM-13669 (dentine from an unworn molar, most likely not contaminated) and GrM-14517 (rib coated with consolidant). Results are identical (5839 ± 25 and 5840 ± 25 uncal BP; Appendix 1), suggesting that pre-treatment was effective in removing the potential effect of consolidant.

However, a careful pre-treatment and sample selection has revealed to be fundamental, especially when measurements involve thin cranial bones covered in plaster for reconstruction purposes. Results obtained for the cranium labeled as AC 6625.1 (GrM-13676, 5647 ± 25 ; re-measuring the same collagen give similar results: GrM-18889, 5671 ± 28) did not overlap with what we determined to be its postcranium, labeled as AC 6626.2 (GrM-13686, 5840 ± 25). However, the selection of a different cranial fragment – distant from the plastered area and

displaying thicker cortical bone – gave results compatible with the postcranium (GrM-18885, 5829±28).

Remains attributed to the same individual, PIP1 001 (Grotta dei Pipistrelli, burial n°3 from Almagro 1954-55 excavations; Appendix 1), were divided in three different museum boxes, and fragments from each box were dated before realizing the common origin of the materials. Two dates (GrM-13618: 5772±25, and GrM-13620: 5799±25) are compatible using the function R_Combine in OxCal 4.3, while the third (GrM-13621, 5882±25) gave a significant X^2 Test ($p < 0.05$). We re-measured the remaining collagen of GrM-13620-21, and obtained virtually identical results, but did not give a significant X^2 Test when combined (GrM-18891, 5799±28; GrM-18940, 5860±28). The remains from Grotta dei Pipistrelli do not appear consolidated, most are still covered in dirt, and are very fragmented. Further research will determine the possible reasons for this small discrepancy, which may also include the third bone fragment not actually belonging to the same individual.

In another instance, two cranial fragments of same individual (PO 034) were dated twice (Pollera 6677a, and a mislabeled fragment from Pollera 6677b, from Issel-Morelli excavations 1892) giving nearly identical results: GrM-13438, 5897±25; GrM-13493, 5901±25 (Appendix 1, Supplementary Information S1).

Finally, in another case the osteological analysis suggested that two dated catalogue numbers (PO 6690bis.1 and PO 6687.1) belonged to the same individual (now coded as PO 032). They gave very similar results (GrM-13435, 5811±25; GrM-13501, 5851±25; Appendix 1, Supplementary Information S1), which did not give a significant X^2 Test when combined.

Figure 2 shows the stack plot, and Figure 3 the curve plot, of the 120 individuals 95.4% probability calibrated BCE ranges. When multiple dates were available for the same individual, they were combined using the function R_combine (OxCal 4.3). Confidence intervals for dates span from c. 5300 BCE to c. 650 CE, with an apparent concentration between 5000 and 4300 BCE. We divided the results based on the traditional chrono-cultural subdivisions in Liguria (Table 3): most individuals [$n = 88$ (98 dates)] fall in the period during which the Neolithic SMP culture was attested in Liguria. Only 6 individuals have ranges falling completely in the sixth millennium BCE, with uncertain cultural attribution (see Discussion), and 2 fall during the

period in which the *Chasséen* cultural tradition was present in Liguria. Fifteen individuals have been dated to Copper Age, 6 to different moments of the Bronze Age, and 3 to after 900 BCE.

Figure 2 and Table 3 about here

4. Discussion

Over the decades, scholars have highlighted the importance of systematic and complete campaigns of radiocarbon determinations aimed at a better understanding of the cultural and population dynamics in the Italian Neolithic (Pearce, 2013; Skeates, 1994, 2003, 2013). This study had undertaken a large-scale direct dating of the skeletal series from Liguria excavated since the late 1800s, and has allowed for an initial assessment of temporal patterns in the mortuary use of caves and variability of funerary behaviors. In addition, the direct dating has restituted importance to a large portion of the skeletal series with little or no contextual information beyond the site of provenience, which is now available for taphonomic re-evaluations through the cross-referencing excavation reports with osteological data (e.g. Sparacello et al., 2018a, b, 2019).

Results indicate that most Neolithic remains, i.e. chronologically overlapping with the successions of Neolithic cultural traditions of Liguria, belong to the period c. 5000-4300 BCE, when the Square Mouthed Pottery Culture (SMP) was attested in this area (Binder and Sénépart, 2010; Del Lucchese and Starnini, 2015; Maggi, 1997a). A few burials whose 95.4% calibrated ^{14}C range spans across the ending of the sixth and beginning of the fifth millennium BCE were tentatively attributed to the early phases of this culture, as suggested in Del Lucchese and Starnini (2015). In the two largest assemblages from Arene Candide Cave (n = 38, including the two dates for Tiné's burials, Table 1) and Grotta Pollera (n = 43, including the date for Pollera 21; Sparacello et al., 2017; Table 1), the vast majority of burials and partial skeletons belong to this phase (84% and 95%, respectively). In other sites such as Bergeggi, all dates refer to this period (n = 7). This datum alone would aid the chrono-cultural attribution of other remains from the same caves and excavation campaigns which could not be dated, or for which the collagen extraction failed (see Supplementary Information Table S1).

In addition, there is now further and definitive evidence of the introduction of a specific kind of burial, the rectangular stone cist formed by flat slab of stones, with the SMP culture (Del Lucchese, 1997). Based on the dated individuals for which we have information about the depositional context (Table 4, details in Supplementary Information Table S2; see also Sparacello et al., 2018b, 2019), it is clear that this funerary structure is absent in earlier and later periods, and is almost exclusively present in SMP adults (both sexes) and in adolescents. The same chrono-cultural attribution can be therefore extended to the other individuals buried in a stone cist that could not be dated due to lack of collagen (Arene Candide 6 PE, excavations Perrando 1874; Arene Candide II, excavations Bernabò Brea 1940-50; Supplementary Information Table S2), or that are reported in the literature but could not be found (e.g. Bernabò Brea, 1946: 220), or accessed (e.g. Issel, 1908: 383-384; Parenti and Messeri, 1962: Tav. 19/IX-21/XI). Future research will take advantage of the new chronological framework to further contextualize the material culture often associated with funerary behavior during the SMP of Liguria, such as eclogite stone axes (Pedrotti, 1996; Garibaldi et al., 2003), and bone and shellfish artifacts (Mazzieri and Micheli, 2014). In addition, comparisons with the numerous burials documented in the Po plain (northern Italy), spanning the different phases of the SMP (Bernabò Brea et al., 2010, 2014), will inform on the regional and temporal variation of funerary behaviors within the same cultural tradition.

Table 4 about here

While the skeletal material contemporaneous to the SMP culture is abundant, few individuals date to the sixth millennium BCE, confirming the substantial rarity of human remains from the earlier phases of the Neolithic of northern Italy. An exception to this pattern is the site of Arma dell'Aquila, in the Finalese, where recent research has shown that most burials and skeletal remains belong to the sixth millennium BCE, and several to its first half (Mannino et al., 2018; Sparacello et al., 2019). In the other Ligurian sites reported here, only nine individuals have a calibrated 95.4% range spanning into the last quarter of the sixth millennium BCE. These do not include Arene Candide V, an adolescent buried in a lithic cist, previously directly dated to the mid-sixth millennium BCE (see Introduction), for which we obtained a more coherent date placing it in the fifth millennium BCE (Appendix 1). Among the nine individuals chronologically spanning into the sixth millennium, only four have information about their

depositional context. The best documented is Arene Candide 2 (Tin  excavations 1973-77), an adult male flexed on his left side, covered with abundant ochre, and deposited in a simple pit opened in ICC layers (Layer 14; Tin , 1976, 1986). Previous direct AMS dating on this individual suggested a later chrono-cultural attribution, possibly *Chass en* (Biagi and Starnini, 2016). The date obtained here is more compatible with the stratigraphic position of the burial reported by the excavators (Tin , 1976, 1986). Unfortunately, Arene Candide 2 Tin  and the contemporaneous depositions from Arma dell'Aquila (Sparacello et al., 2018, 2019) do not have material culture directly associated with the skeleton: further archeological research beyond direct dating is necessary to attribute more precisely these burials to a specific cultural tradition within the Impresso-Cardial cultural complex (Binder and S n part, 2010).

Even rarer are the human remains chronologically overlapping with the diffusion in Liguria of the *Chass en* tradition (c. 4300-3700 BCE; Crepaldi, 2001; Maggi, 1997a), consisting of a perinatal from Grotta Pollera (excavations Rossi 1885-1892; Issel, 1908: 338), and a partially disturbed deposition of a late adolescent or young adult from Arma di Nasino (excavations Anfossi 1961-74; Appendix 1; Supplementary Information Table S1). Also in this case, a direct connection of the skeleton with material culture present at Arma di Nasino – spanning from the Upper Paleolithic to the Bronze Age – is not present (Scotti, 1999). Interestingly, Nasino 1 is the only burial in the skeletal series that is surrounded by stones (Scotti, 1999: 155), rather than being in a simple pit or enclosed in a stone cist. More research is necessary to determine whether this detail adds to the characterization of diachronic patterns in Neolithic funerary behaviors in Liguria. In general, the presence of a gap between the latest SMP burials and the two burials pertaining to the end of the fifth / beginning of the fourth millennium BCE highlights the need for further research in order to clarify the funerary and population dynamics with the spread of the *Chass en* tradition in Liguria.

After this *quasi-hiatus* of over five hundred years in the evidence of funerary use of caves between c. 4300-3700, human remains become more common, with decreasing frequency from the Copper Age to the Iron Age (Table 3 and Appendix 1). The findings confirm the long-term use of certain caves for funerary activity (Arene Candide, Camere, Pollera, and Pipistrelli), and are compatible with the numerous reports of commingled assemblages directly dated to the Copper and Bronze Age in Finalese caves (e.g. Arobba et al., 2013; Del Lucchese, 2008; Del

Lucchese and Maggi, 1998). However, our results add new information to the characterization of funerary variability in the Copper Age of Liguria: in addition to commingled assemblages, remains dated here comprise a secondary burial “*a pozzetto*” (“well burial”; Grotta dell’Acqua; Cornaggia Castiglioni, 1961), and four partial skeletons, including an almost complete perinatal from Arene Candide (AC 6635.1; Appendix 1, and Supplementary Information Table S1). Similarly, finding non-combusted human remains from the Iron Age was not expected, and deserves further investigation given the prevalence in Liguria of the practice of cremation at the end of the Bronze Age (e.g. Paltineri, 2010).

The double burial from Boragni, “surrounded by large stones”, and including two skeletons without grave goods (Bernabò Brea, 1947: 85), had originally a Neolithic attribution (Parenti and Messeri, 1962), but now it dates to historic times, when the Byzantine Empire dominated over Liguria. The use of Finalese caves and rock shelters at the time is well-known, but never attested for funerary purposes (Bernabò Brea, 1956; De Vingo, 2018; Murialdo, 1989). Further research will investigate how this double burial relates to the chrono-cultural context of Late Antiquity in Liguria.

Overall, this dating campaign has significantly improved our knowledge of the chronology and composition of the skeletal series from Liguria. Previously, only a dozen burials from a few excavation campaigns, virtually all from Arene Candide, could be reasonably attributed to the SMP Neolithic based on stratigraphic evidence and associated finds (Bernabò Brea, 1946, 1956; Canci et al., 1999; Canci and Del Lucchese, 2003; Formicola, 1986; Odetti, 1991; Tiné, 1976, 1986, 1999). As explained above, for two of them the radiocarbon dating gave inconsistent results (Le Bras-Goude et al., 2006; Biagi and Starnini, 2016), which have been corrected here. In general, the attribution to the SMP, when proposed in those studies, was correct. However, in contrast with that dozen, more than a hundred individuals were labelled as “uncertain” (see Parenti and Messeri, 1962), including virtually all individuals from large skeletal series such as Pollera and most of the children. The work done here, and in recent re-assessments (Mannino et al., 2018; Sparacello et al., 2018b, 2019), has returned to the scientific community one of the largest Neolithic skeletal collections in Europe, composed by more than a hundred individuals from all classes of age, which is now being better characterized in terms of demography, activity, diet, life history, and paleopathology (e.g. Dori et al., in review.; Goude et al., in review;

Orellana-Gonzales et al., in review; Varalli et al., in review). In addition, this study has clarified the chronological status of several commingled assemblages and isolated findings.

5. Conclusions

The history of anthropological research in Liguria is almost as old as the discipline itself, and the skeletal remains from this region always had an important place in the debate on the Neolithic peopling of the western Mediterranean. However, the often poor quality of the documentation associated with these remains significantly limited the potential of this skeletal series for modern anthropological studies. This study is part of a renewed collaborative attempt towards obtaining higher-resolution information through the comprehensive survey of all the available funerary and osteological data from the extant skeletal series from Liguria, re-analyzing the available documentation from past excavations, and cross-referencing the resulting information with a refined absolute chronology. The 130 new dates on human bone presented here significantly improve the chronological characterization of the skeletal series unearthed between the late 1800s and the 1990s in the Finalese area, allow for an initial assessment of patterns in Neolithic funerary use of Ligurian caves, and set the basis for upcoming multidisciplinary studies.

Results indicate that few remains can be attributed to the last quarter of the sixth millennium BCE, with uncertain attribution within the Impresso-Cardial cultural complex, and that the great majority of burials and partial skeletons ($n = 88$) chronologically overlap with the Square Mouthed Pottery culture, which characterizes the fifth millennium BCE in Liguria. The cultural or demographic implications of this emphasis in the funerary use of caves in this period will be explored in future research, but the present paper aided the characterization of its funerary practices.

After this widespread use of caves for funerary purposes, the dates suggest a dramatic decrease until the Copper Age, when caves were used for collective inhumations. Few remains from the Bronze Age, Iron Age, and Byzantine period, confirm the long-term tradition of use of Ligurian caves for funerary purposes from the Upper Paleolithic to historic times.

Future research will build upon the framework created here to further characterize funerary practices, bio-cultural adaptations, and social reproduction in the Neolithic of Liguria. The cultural attributions are necessarily broad in this work, and will be refined through further

archaeological studies of the material evidence associated to burials. Future improvements will include Bayesian modelling on the dates presented here. This can only be achieved by incorporating information from ongoing systematic reviews of old excavation contexts (similarly to the one recently conducted at Arma dell'Aquila, Sparacello et al. 2018b; 2019) and the completion of the study of the stratigraphic series recently investigated on the key-site of Arene Candide Cave (excavations Maggi, Panelli and Rossi 1997-2012). Finally, we will attempt to extend this work of recovery and valorization of old collections and documentation to the material that is still considered lost, or was not accessible for the present study.

Appendix 1 about here

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Lab Code	Reference	Individual	Excavation	Museum	14C Age (yr BP)	Chrono-cultural attribution	CalBCE 95.4%
GX 16931-A	Del Lucchese, 1997	Arene Candide 6PE	Perrando 1874	MAL	6255±240	ICC-SMP	5657-4620
KIA-28340	Le Bras-Goude et al., 2006)	Arene Candide V BB	Bernabò Brea 1940-50	MAF	6570±35	ICC	5612-5477
Beta 109797	Maggi, unpublished	Arene Candide V BB	Bernabò Brea 1940-50	MAF	6370±70	ICC	5476-5221
GX 16962-G	Del Lucchese, 1997	Arene Candide VI BB	Bernabò Brea 1940-50	MAL	5260±135	SMP-Chasséen	4356-3777
GX 16963-G	Del Lucchese, 1997	Arene Candide VII BB	Bernabò Brea 1940-50	MAF	6255±255	ICC-SMP	5666-4611
Beta 109802	Maggi, unpublished	Arene Candide T1 Tinè	Tiné 1973-76	MAF	5700±60	SMP	4704-4374
MAMS-11443	Biagi and Starnini, 2016	Arene Candide T2 Tinè	Tiné 1973-76	MAF	5178±25	Chasséen	4041-3956
Beta 109801	Maggi, unpublished	Arene Candide T3 Tinè	Tiné 1973-76	MAF	5790±60	SMP	4782-4502
Beta-409341	Sparacello et al., 2017	Pollera 21	Rossi 1885-1892	MAL	5820±30	SMP	4779-4587
Combined (OxA-V-2365-37; GrN-17730)	Mannino et al., 2018; Sparacello et al., 2019	Arma dell'Aquila Z1	Zambelli 1934	MAF	5804 ± 33 5800 ± 90	SMP	4724-4552
OxA-V-2365-36	Mannino et al., 2018; Sparacello et al., 2019	Arma dell'Aquila R1	Richard 1938, 1942	MAF	6318 ± 33	ICC	5361-5220
Combined (OxA-V-2365-35; GrA-38258)	Mannino et al., 2018; Sparacello et al., 2019	Arma dell'Aquila R2	Richard 1938, 1942	MAF	6155 ± 34 6125 ± 35	ICC	5208-5003
Combined (OxA-V-2365-34; OxA-V-2365-33; GrA-38328; GrA-38257)	Mannino et al., 2018; Sparacello et al., 2019	Arma dell'Aquila R3	Richard 1938, 1942	MAF	6029 ± 33 6114 ± 32 5985 ± 35 6315 ± 35	ICC	5202-4962
GrM-14531	Sparacello et al., 2019	Arma dell'Aquila R4	Richard 1938, 1942	MAF	6447 ± 18	ICC	5475-5374
OxA-V-2365-32	Mannino et al., 2018; Sparacello et al., 2019	Arma dell'Aquila R5	Richard 1938, 1942	MAF	6118 ± 33	ICC	5208-4956
OxA-V-2365-31	Mannino et al., 2018; Sparacello et al., 2019	Arma dell'Aquila R6	Richard 1938, 1942	MAF	6678 ± 33	ICC	5658-5536
Lyon-14594	Sparacello et al., 2019	Arma dell'Aquila R7	Richard 1938, 1942	MAF	6675 ± 35	ICC	5657-5533
Lyon-14595	Sparacello et al., 2019	Arma dell'Aquila R8	Richard 1938, 1942	MAF	6670 ± 35	ICC	5646-5527
Lyon-14590	Sparacello et al., 2019	Arma dell'Aquila RS1	Richard 1938, 1942	MAF	6770 ± 30	ICC	5720-5631
OxA-2365-51	Mannino et al., 2018; Sparacello et al., 2019	Arma dell'Aquila RS2	Richard 1938, 1942	MAF	5738 ± 33	SMP	4686-4501
OxA-2365-50	Mannino et al., 2018; Sparacello et al., 2019	Arma dell'Aquila RS3	Richard 1938, 1942	MAF	6669 ± 34	ICC	5644-5528
Lyon-14591	Sparacello et al., 2019	Arma dell'Aquila RS4	Richard 1938, 1942	MAF	6105 ± 30	ICC	5207-4940
Lyon-14592	Sparacello et al., 2019	Arma dell'Aquila RS5	Richard 1938, 1942	MAF	6825 ± 35	ICC	5764-5640
Lyon-14593	Sparacello et al., 2019	Arma dell'Aquila RS6	Richard 1938, 1942	MAF	6830 ± 35	ICC	5777-5642
GrM-15910	Sparacello et al., 2019	Arma dell'Aquila RS7	Richard 1938, 1942	MAF	6470 ± 30	ICC	5484-5372
Lyon-14596	Sparacello et al., 2019	Arma dell'Aquila RS9	Richard 1938, 1942	MAF	6095 ± 30	ICC	5206-4911

Table 1 – The known radiocarbon dates on human bone prior to the publication of this study. MAF: Museo Archeologico del Finale; MAL: Museo di Archeologia Ligure. ICC: Impresso-Cardial Complex (Binder and S  n  part, 2010; Arobba et al., 2017); SMP: Square Mouthed Pottery (Maggi, 1997a; Pearce, 2013); Chass  en (Maggi, 1997a; Crepaldi, 2001; Binder et al., 2008).

Site	Excavation	Burials or disturbed burials	Disarticulated or partial skeletons	Scattered remains
Arene Candide	Amerano 1887-1897		1	
	Morelli and Morelli-Issel 1884-87	2	16 (19)	
	Rossi (uncertain)		1	
	Bernabò Brea 1940-50	8	3	3
	Tiné 1973-76	1		
	Del Lucchese 1986	1		
Grotta dell'Acqua	Cornaggia Castiglioni 1958	1		
Arma delle Anime	Giuggiola 1963-64			2
Battorezza	Dentella 1950-60			5
Bergeggi	Modigliani 1880	5	1	
	Giuggiola 1968			1
Boragni	Crowfoot 1907-1909	1		
Camere	Anfossi 1961-74			3
Mandurea	Silla 1932			3
Arma del Morto	Amerano 1890s		2	
Caverna della Matta o del Sanguinetto	Rossi 1890?		2	
Arma di Nasino	Anfossi 1961-74	1		
Arma dei Parmorari	Richard 1931-33			3
Pian del Ciliegio	Del Lucchese 1995	2		
Grotta dei Pipistrelli	Almagro 1954-55	6 (10)		2
Grotta Pollera	Morelli 1885-1886	2	2	
	Rossi 1885-1892		26	
	Issel-Morelli 1892	1 (2)	6 (8)	1
	Amerano 1890s	1		
	Tiné 1972	1		
	Gruppo Speleologico Alassio 1981		1	
	Uncertain		1	
Arma Strapatente	Franconi 1960s	2		

Table 2 – Number of burials/partial skeletons/scattered remains analyzed (number of samples in parentheses), by site and excavation campaign.

	Neolithic			Metal Ages			Historic Times
Date cal BCE	5300-5000	5000-4300	4300-3700	3700-2200	2200-900	900-180	180 BCE-643 CE
Chrono-cultural attribution	ICC ¹	SMP	Chasséen	Copper Age	Bronze Age	Iron Age	Roman and Byzantine
Arene Candide	2	33 (30) ²		3		1	
Grotta dell'Acqua				1			
Arma delle Anime				1		1	
Battorezza				1	4		
Bergeggi		7					
Boragni							1
Camere	1			1	1		
Mandurea				3			
Arma del Morto	1	1					
Matta-Sanguinetto	2						
Arma di Nasino			1				
Arma dei Parmorari				2	1		
Pian del Ciliegio		2					
Grotta dei Pipistrelli		10 (6) ^{3,4}		2			
Grotta Pollera		43 (40) ⁵	1	1			
Arma Strapatente		2 ³					
Total	6	98 (88)	2	15	6	2	1

Table 3 – Chrono-cultural attribution of the human remains included in this study, based on the results of the radiocarbon age determination. Number of samples outside of parentheses, number of individuals in parentheses. For most of the remains, a direct association with artefacts belonging to the different cultural traditions is absent, therefore the attribution should be considered a hypothesis. ICC: Impresso-Cardial Complex (Binder and S  n  part, 2010; Arobba et al., 2017); SMP: Square Mouthed Pottery (Maggi, 1997a; Pearce, 2013); Chass  en (Maggi, 1997a; Crepaldi, 2001; Binder et al., 2008). ¹ All remains pertain to the last quarter of the sixth millennium BCE; based on current archaeological evidence, it is not possible an attribution to a specific cultural tradition within the Impresso-Cardial cultural complex. ² One individual from Arene Candide has 4 dates; ³ Includes individuals having part of the 95.4% range falling into the fifth millennium BCE (Appendix 1). ⁴ One individual from Pipistrelli has 5 dates. ⁵ Three individuals from Pollera have 2 dates.

	Burial Type		
ICC-POSTC	Stone cist	Simple pit	Stone circle
Adult		6	
Adolescent			
Infant		5	
SMP	Stone cist	Simple pit	Stone circle
Adult	17	3	
Adolescent	3	1	
Infant	1	15	
Chasséen	Stone cist	Simple pit	Stone circle
Adult			1
Adolescent			
Infant		1	

Table 4 – The directly dated individuals divided by class of age and type of burial (details in Supplementary Information Table S2).

Lab Code	BUR.DEN. Indiv code	Site	Museum	Individual	Individual depositional context	Excavation	Burial number	Age Class	14C Age (yr BP)	Cal BCE 95.4%	Chrono cultural attribution (possible) ¹
GrM-15874	ACN 001	Arene Candide	MAF	AC AMERANO	Disarticulated/partial skeleton	Amerano 1887-1897	Undet.	Infans	5780±30	4707-4550	SMP
GrM-13671	ACN 003	Arene Candide	MSNF	AC 6626.1	Disarticulated/partial skeleton	Morelli-Issel 1884-1887	Undet.	Adult	5862±25	4792-4688	SMP
GrM-13674	ACN 004	Arene Candide	MSNF	AC 6623.1	Disarticulated/partial skeleton	Morelli 1884-1887	Tomba 6?	Infans	5828±25	4779-4608	SMP
GrM-13686	ACN 005	Arene Candide	MSNF	AC 6626.2 (postcranium)	Disarticulated/partial skeleton	Morelli-Issel 1884-1887	Undet.	Infans	5840±25	4786-4616	SMP
GrM-18885	ACN 005	Arene Candide	MSNF	AC 6625.1 (cranium)	Disarticulated/partial skeleton	Morelli 1884-1887	Undet.	Infans	5829±28	4781-4607	SMP
GrM-13676	ACN 005	Arene Candide	MSNF	AC 6625.1 (cranium with plaster)	Disarticulated/partial skeleton	Morelli 1884-1887	Undet.	Infans	5647±25	4544-4399	SMP
GrM-18889	ACN 005	Arene Candide	MSNF	AC 6625.1 (cranium with plaster, re-measured)	Disarticulated/partial skeleton	Morelli 1884-1887	Undet.	Infans	5671±28	4578-4450	SMP
GrM-13679	ACN 006	Arene Candide	MSNF	AC 6622.1	Disarticulated/partial skeleton	Morelli 1884-1887	Tomba 2?	Adult	6135±25	5208-5000	ICC
GrM-13681	ACN 007	Arene Candide	MSNF	AC 6630.1	Disarticulated/partial skeleton	Morelli 1884-1887	Tomba 9?	Infans	5734±25	4682-4502	SMP
GrM-13682	ACN 008	Arene Candide	MSNF	AC 6730.1	Disarticulated/partial skeleton	Morelli 1884-1887	Undet.	Adult	5755±25	4688-4540	SMP
GrM-13683	ACN 009	Arene Candide	MSNF	AC 6632.1	Disarticulated/partial skeleton	Morelli 1884-1887	Tomba 14?	Infans	5809±25	4726-4557	SMP
GrM-13684	ACN 010	Arene Candide	MSNF	AC 6621.1	Disarticulated/partial skeleton	Morelli 1884-1887	Tomba 15?	Adolescent	5809±25	4726-4557	SMP
GrM-13414	ACN 011	Arene Candide	MSNF	AC 6629.1	Disarticulated/partial skeleton	Morelli 1884-1887	Tomba 8?	Infans	5815±25	4767-4586	SMP
GrM-13419	ACN 012	Arene Candide	MSNF	AC 6631.1	Disarticulated/partial skeleton	Morelli 1884-1887	Tomba 11?	Infans	5768±25	4691-4545	SMP
GrM-13424	ACN 013	Arene Candide	MSNF	AC 6628.1	Disarticulated/partial skeleton	Morelli 1884-1887	Tomba 4?	Infans	5818±25	4768-4592	SMP
GrM-14487	ACN 014	Arene Candide	MAL	AC7PE	Burial	Morelli 1884-1887	2 Issel 1908	Adult	5815±25	4767-4586	SMP
GrM-14488	ACN 015	Arene Candide	MAL	AC8PE	Burial	Morelli 1884-1887	1 Issel 1908	Adult	5786±25	4708-4555	SMP
GrM-13417	ACN 018	Arene Candide	MSNF	AC 6626 bis.1	Disarticulated/partial skeleton	Morelli-Issel 1884-1887	Undet.	Infans	5853±25	4792-4621	SMP
GrM-13420	ACN 019	Arene Candide	MSNF	AC 6627.1	Disarticulated/partial skeleton	Morelli-Issel 1884-1887	Undet.	Infans	5763±25	4690-4544	SMP
GrM-13422	ACN 020	Arene Candide	MSNF	AC 6633.1	Disarticulated/partial skeleton	Morelli-Issel 1884-1887	Undet.	Infans	5810±25	4726-4557	SMP
Lyon-14586	ACN 022	Arene Candide	MAF	AC BB RS Zone G 13°T = 22	Scattered/isolated/ commingled remains	Bernabò Brea 1940-1950	Undet.	Infans	5915±30	4847-4715	SMP
Lyon-14587	ACN 023	Arene Candide	MAF	AC BB RS G1 11°T = 22	Scattered/isolated/ commingled remains	Bernabò Brea 1940-1950	Undet.	Infans	5895±30	4836-4709	SMP
GrM-19463	ACN 025	Arene Candide	MSNF	AC (prob) indet adult postcr 1 Morelli (prob)	Disarticulated/partial skeleton	Morelli 1884-1887	Undet.	Adult	5830±30	4784-4605	SMP
GrM-14505	ACN 026	Arene Candide	MAL	AC BB RS Z.H tl.27 = 23 H 3/6/1950	Scattered/isolated/ commingled remains	Bernabò Brea 1940-1950	Undet.	Infans	5865±25	4791-4690	SMP
GrM-16990	ACN 027	Arene Candide	MSNF	AC 6731.1 (AC I BB)	Burial	Bernabò Brea 1940-1950	Tomba I	Adolescent	5765±25	4690-4544	SMP
GrM-15875	ACN 029	Arene Candide	MAF	AC III BB	Burial	Bernabò Brea 1940-1950	Tomba III	Adult	5860±30	4800-4619	SMP

GrM-13673	ACN 030	Arene Candide	MSNF	AC6726.4 (Prob. AC IV BB)	Burial	Bernabò Brea 1940-1950	Tomba IV	Adolescent	5813±25	4766-4558	SMP
GrM-14528	ACN 031	Arene Candide	MAF	AC V BB	Burial	Bernabò Brea 1940-1950	Tomba V	Adult	5800±25	4720-4557	SMP
GrM-14499	ACN 032	Arene Candide	MAL	AC VI BB	Burial	Bernabò Brea 1940-1950	Tomba VI	Adult	5685±25	4581-4457	SMP
GrM-14530	ACN 033	Arene Candide	MAF	AC VII BB	Burial	Bernabò Brea 1940-1950	Tomba VII	Adult	5825±25	4778-4603	SMP
Lyon-14585	ACN 034	Arene Candide	MAF	AC VIII BB	Burial	Bernabò Brea 1940-1950	Tomba VIII	Infans	5860±30	4800-4619	SMP
GrM-14526	ACN 035	Arene Candide	MAF	AC IX BB	Burial	Bernabò Brea 1940-1950	Tomba IX	Adult	5830±25	4779-4611	SMP
GrM-14507	ACN 037	Arene Candide	MAL	AC BB infant layer 22 IX	Disarticulated/partial skeleton	Bernabò Brea 1940-1950	Undet.	Infans	5795±25	4714-4556	SMP
GrM-16975	ACN 040	Arene Candide	MAF	AC T2 Tinè	Burial	Tiné 1973-76	Tomba 2	Adult	6145±25	5209-5011	ICC
Lyon-14584	ACN 042	Arene Candide	MAF	AC 1 DL	Burial	Del Lucchese 1986	1 Del Lucchese	Infans	5835±30	4785-4610	SMP
GrM-13415	ACM 001	Arene Candide	MSNF	AC 6635.1	Disarticulated/partial skeleton	Morelli-Issel 1884-1887	Undet.	Infans	4121±25	2865-2580	Copper Age
GrM-13672	ACM 002	Arene Candide	MSNF	AC 6808.1	Disarticulated/partial skeleton	Rossi? Uncertain	Undet.	Adult	4485±25	3341-3091	Copper Age
GrM-14500	ACM_003	Arene Candide	MAL	AC BB RS mandible II = 21	Scattered/isolated/commingled remains	Bernabò Brea 1940-1950	Undet.	Adult	2755±20	971-834	Iron Age
GrM-14504	ACM_004	Arene Candide	MAL	AC BB RS fragment cranium H7	Scattered/isolated/commingled remains	Bernabò Brea 1940-1950	Undet.	Adult	4490±20	3339-3096	Copper Age
GrM-15873	ACQ 001	Grotta dell'Acqua	MAF	Acqua Cornaggia 1,III,55	Burial	Cornaggia Castiglioni 1958	Tomba 1	Adult	4445±30	3333-2938	Copper Age
Lyon-14597	ANI 001	Arma delle Anime	MAF	Anime RS Giuggiola A	Scattered/isolated/commingled remains	Giuggiola 1963-64	Undet.	Adolescent	2485±30	776-488	Iron Age
Lyon-14598	ANI 002	Arma delle Anime	MAF	Anime RS Giuggiola C4 1657	Scattered/isolated/commingled remains	Giuggiola 1963-64	Undet.	Child	3880±30	2467-2236	Copper Age
GrM-15914	BAT 001	Battorezza	MAF	BAT RS phal A	Scattered/isolated/commingled remains	Dentella 1950s	Undet.	Adult	3720±25	2199-2035	Bronze Age
GrM-15915	BAT 002	Battorezza	MAF	BAT RS cranium B	Scattered/isolated/commingled remains	Dentella 1950s	Undet.	Adult	3465±25	1881-1695	Bronze Age
GrM-15916	BAT 003	Battorezza	MAF	BAT RS petrous FIN 001	Scattered/isolated/commingled remains	Dentella 1950s	Undet.	Adult	4105±30	2864-2506	Copper Age
GrM-15917	BAT 004	Battorezza	MAF	BAT RS petrous FIN 002	Scattered/isolated/commingled remains	Dentella 1950s	Undet.	Adult	3485±25	1886-1703	Bronze Age
GrM-15919	BAT 005	Battorezza	MAF	BAT RS petrous FIN 003	Scattered/isolated/commingled remains	Dentella 1950s	Undet.	Adult	3335±30	1691-1528	Bronze Age
GrM-14518	BER 001	Bergeggi	MAL	BER 1	Burial	Modigliani 1880	Tomba 1	Adolescent	5630±25	4527-4370	SMP
GrM-14812	BER 002	Bergeggi	MAL	BER 2	Burial	Modigliani 1880	Tomba 2	Adult	5725±25	4680-4494	SMP
GrM-14523	BER 003	Bergeggi	MAL	BER 3	Burial	Modigliani 1880	Tomba 3	Adult	5605±25	4488-4364	SMP
GrM-14524	BER 004	Bergeggi	MAL	BER 4	Burial	Modigliani 1880	Tomba 4	Adult	5725±25	4680-4494	SMP
GrM-14814	BER 005	Bergeggi	MAL	BER 5	Burial	Modigliani 1880	Tomba 5	Adult	5640±25	4539-4374	SMP
GrM-13617	BER 006	Bergeggi	MAF	BER RS 68	Scattered/isolated/commingled remains	Giuggiola 1968	Undet.	Undet.	5657±25	4546-4448	SMP
GrM-16987	BER 007	Bergeggi	MSNF	BER 1172 0472 bag 01178 6897	Disarticulated/partial skeleton	Modigliani 1880	Undet.	Adult	6065±25	5047-4857	SMP

Lyon-14599	BOR 001	Boragni	MAF	BOR I	Burial	Crowfoot 1907-1909	Tomba I	Adult	1460±30	553-648 CE	Byzantine
GrM-13518	CAM 001	Camere	SOPR GE	CAM vert	Scattered/isolated/ commingled remains	Anfossi 1961-74	Undet.	Adult	6146±25	5209-5011	ICC
GrM-13516	CT 001	Camere/ Camerotto	SOPR GE	CT2 A	Scattered/isolated/ commingled remains	Anfossi 1961-74	Undet.	Adult	3688±25	2190-1980	Bronze Age
GrM-13517	CT 002	Camere/ Camerotto	SOPR GE	CT2 B	Scattered/isolated/ commingled remains	Anfossi 1961-74	Undet.	Adult	4056±25	2835-2488	Copper Age
Lyon-14600	MAND 001	Mandurea	MAF	MAND I ind A	Disarticulated/partial skeleton	Silla 1932	Undet.	Adult	4760±30	3639-3384	Copper Age
GrM-16977 ¹	MAND 002	Mandurea	MAF	MAND 15 IV 1 frag 1	Scattered/isolated/ commingled remains	Silla 1932	Undet.	Adult	4655±25	3517-3366	Copper Age
GrM-15881	MAND 003	Mandurea	MAF	MAND 15 IV 1 frag 2	Scattered/isolated/ commingled remains	Silla 1932	Undet.	Adult	4825±30	3661-3526	Copper Age
GrM-14494	MOR 001	Arma del Morto	MAL	Morto T 251	Disarticulated/partial skeleton	Amerano 1890s	Undet.	Adult	5875±25	4797-4695	SMP
GrM-14495	MOR 002	Arma del Morto	MAL	Morto T 253	Disarticulated/partial skeleton	Amerano 1890s	Undet.	Adult	6230±25	5301-5073	ICC
GrM-19457	MS 001	Matta- Sanguineto	MSNF	La Matta 01081	Disarticulated/partial skeleton	Rossi 1890?	Undet.	Infans	6165±35	5216-5011	ICC
GrM-19458	MS 002	Matta- Sanguineto	MSNF	La Matta 01088	Disarticulated/partial skeleton	Rossi 1890?	Undet.	Infans	6130±30	5209-4992	ICC
GrM-15880	NAS 001	Arma di Nasino	MNA	Nasino 1	Disturbed burial	Anfossi 1961-74	Tomba 1	Adolescent	5285±30	4232-4000	Chasséen
Lyon-14601	PARM 001	Parmorari	MAF	PARM RS Richard mandible fragm.	Scattered/isolated/ commingled remains	Richard 1931-33	Undet.	Infans	4460±30	3337-3021	Copper Age
Lyon-14602	PARM 002	Parmorari	MAF	PARM RS Richard maxill. fragm.	Scattered/isolated/ commingled remains	Richard 1931-33	Undet.	Infans	3035±30	1397-1211	Bronze Age
GrM-15945	PARM 003	Parmorari	MAF	PARM RS Richard 1931- 32 tooth	Scattered/isolated/ commingled remains	Richard 1931-33	Undet.	Adolescent	4030±25	2620-2475	Copper Age
GrM-13520	PdC 001	Pian del Ciliegio	MAF	PdC adulto	Disturbed burial	De Lucchese 1995	Tomba 1	Adult	5764±25	4690-4544	SMP
GrM-13519	PdC 002	Pian del Ciliegio	MAF	PdC bambino	Disturbed burial	De Lucchese 1995	Tomba 2	Infans	5790±25	4711-4555	SMP
GrM-13618 ²	PIPI 001	Pipistrelli	MAF	PIPI 3 El Muerto N3 23.III.55	Burial	Almagro 1954-1955	Tomba 3	Adult	5772±25	4701-4547	SMP
GrM-13620 ²	PIPI 001	Pipistrelli	MAF	PIPI 3 El Muerto N3 23.III.56	Burial	Almagro 1954-1955	Tomba 3	Adult	5799±25	4719-4557	SMP
GrM-18891	PIPI 001	Pipistrelli	MAF	PIPI 3 El Muerto N3 23.III.56 collagen re- measured	Burial	Almagro 1954-1955	Tomba 3	Adult	5799±28	4719-4556	SMP
GrM-13621 ²	PIPI 001	Pipistrelli	MAF	PIPI 3 El Muerto N3 23.I.1	Burial	Almagro 1954-1955	Tomba 3	Adult	5882±25	4825-4704	SMP
GrM-18940	PIPI 001	Pipistrelli	MAF	PIPI 3 El Muerto N3 23.I.1 collagen re-measured	Burial	Almagro 1954-1955	Tomba 3	Adult	5860±28	4798-4621	SMP
GrM-15884	PIPI 002	Pipistrelli	MAF	PIPI 1 23.I.2 JUV	Burial	Almagro 1954-1955	Tomba 1	Infans	5770±30	4703-4545	SMP
GrM-15883	PIPI 003	Pipistrelli	MAF	PIPI 4 23.III.73 76	Burial	Almagro 1954-1955	Tomba 4	Adult	6095±35	5207-4909	SMP
Lyon-14606	PIPI 004	Pipistrelli	MAF	PIPI 5 23.I.28 Cirillo	Burial	Almagro 1954-1955	Tomba 5	Adult	6040±30	5016-4844	SMP
Lyon-14605	PIPI 005	Pipistrelli	MAF	PIPI 6 23.II.41 Angelina	Burial	Almagro 1954-1955	Tomba 6	Adult	6015±30	4995-4810	SMP
GrM-13355	PIPI 006	Pipistrelli	MAF	PIPI 7 24.III.104	Burial	Almagro 1954-1955	Tomba 7	Adult	6092±30	5206-4909	SMP
GrM-15911	PIPI 007	Pipistrelli	MAF	PIPI 23 IV 82	Scattered/isolated/ commingled remains	Almagro 1954-1955	Undet.	Adult	4040±30	2832-2474	Copper Age

Lyon-14604	PIPI 008	Pipistrelli	MAF	PIPI 23.II.54 RS with fauna (bear)	Scattered/isolated/commingled remains	Almagro 1954-1955	Undet.	Adult	4930±30	3771-3651	Copper Age
GrM-14497	PO 001	Pollera	MAL	PO 13 PE	Burial	Morelli 1885-1886	Tomba I	Adult	5745±25	4686-4527	SMP
GrM-14509	PO 002	Pollera	MAL	PO 10 PE	Burial	Morelli 1885-1886	Tomba II	Adult	5777±25	4701-4550	SMP
GrM-13425	PO 003	Pollera	MSNF	PO 6675.4	Disarticulated/partial skeleton	Rossi 1885-1892	Undet.	Adult	5750±25	4687-4535	SMP
GrM-13429	PO 004	Pollera	MSNF	PO 6670.1	Disarticulated/partial skeleton	Rossi 1885-1892	Tomba 15?	Infans	5734±25	4682-4502	SMP
GrM-13430	PO 005	Pollera	MSNF	PO 6673.2	Disarticulated/partial skeleton	Rossi 1885-1892	Undet.	Infans	5809±25	4726-4557	SMP
GrM-13432	PO 006	Pollera	MSNF	PO 6673.6	Disarticulated/partial skeleton	Rossi 1885-1892	Undet.	Adult	5929±25	4879-4724	SMP
GrM-13433	PO 007	Pollera	MSNF	PO 6673.3	Disarticulated/partial skeleton	Rossi 1885-1892	Undet.	Infans	5816±25	4768-4587	SMP
GrM-13434	PO 008	Pollera	MSNF	PO 6673.5	Disarticulated/partial skeleton	Rossi 1885-1892	Undet.	Infans	5792±25	4712-4556	SMP
GrM-13437	PO 009	Pollera	MSNF	PO 6686.1	Disarticulated/partial skeleton	Rossi 1885-1892	Undet.	Infans	5785±25	4707-4555	SMP
GrM-13494	PO 010	Pollera	MSNF	PO 6666.2 (6666+6666bis)	Disarticulated/partial skeleton	Rossi 1885-1892	Undet.	Infans	5792±25	4712-4556	SMP
GrM-13496	PO 011	Pollera	MSNF	PO 6678.1	Disarticulated/partial skeleton	Rossi 1885-1892	Tomba 4?	Infans	5859±25	4794-4686	SMP
GrM-13497	PO 012	Pollera	MSNF	PO 6667.1	Disarticulated/partial skeleton	Rossi 1885-1892	Undet.	Infans	5911±25	4838-4722	SMP
GrM-13503	PO 013	Pollera	MSNF	PO 6663.1	Disarticulated/partial skeleton	Rossi 1885-1892	Tomba 2?	Infans	5775±25	4701-4548	SMP
GrM-13504	PO 014	Pollera	MSNF	PO 6664.1	Disarticulated/partial skeleton	Rossi 1885-1892	Tomba 3?	Infans	5637±25	4536-4373	SMP
GrM-13507	PO 015	Pollera	MSNF	PO 6684.1	Disarticulated/partial skeleton	Rossi 1885-1892	Tomba 9?	Infans	5803±25	4722-4558	SMP
GrM-13508	PO 016	Pollera	MSNF	PO 6676.1	Disarticulated/partial skeleton	Rossi 1885-1892	Undet.	Adolescent	5799±25	4719-4557	SMP
GrM-13509	PO 017	Pollera	MSNF	PO 6665.1	Disarticulated/partial skeleton	Rossi 1885-1892	Tomba 7?	Infans	5041±25	3946-3775	Chasséen
GrM-13511	PO 018	Pollera	MSNF	PO 6672.1	Disarticulated/partial skeleton	Rossi 1885-1892	Tomba 14?	Infans	5672±25	4548-4455	SMP
GrM-13513	PO 019	Pollera	MSNF	PO 6669.1	Disarticulated/partial skeleton	Rossi 1885-1892	Tomba 10?	Infans	5794±25	4712-4587	SMP
GrM-14490	PO 020	Pollera	MAL	PO 14P E	Disarticulated/partial skeleton	Rossi 1885-1892	Tomba 6?	Adult	5840±25	4786-4616	SMP
GrM-14492	PO 021	Pollera	MAL	PO 12 PE	Disarticulated/partial skeleton	Rossi 1885-1892	Tomba 5?	Adult	5860±25	4794-4687	SMP
GrM-14498	PO 023	Pollera	MAL	PO 30 PE	Disarticulated/partial skeleton	Rossi 1885-1892	Tomba 3?	Adult	5760±25	4689-4543	SMP
GrM-14508	PO 024	Pollera	MAL	PO 110C PE	Disarticulated/partial skeleton	Rossi 1885-1892?	Undet.	Infans	5765±25	4690-4544	SMP
GrM-14510	PO 025	Pollera	MAL	PO 22 PE	Disarticulated/partial skeleton	Rossi 1885-1892	Tomba 1?	Adult	5840±25	4786-4616	SMP
GrM-14512	PO 026	Pollera	MAL	PO 33 PE	Disarticulated/partial skeleton	Rossi 1885-1892	Tomba 8?	Adult	5790±25	4711-4555	SMP
GrM-14514	PO 027	Pollera	MAL	PO 20 PE	Disarticulated/partial skeleton	Rossi 1885-1892	Tomba 12?	Infans	5795±25	4715-4556	SMP
GrM-14515	PO 028	Pollera	MAL	PO 34 PE	Disarticulated/partial	Rossi 1885-1892	Tomba 2?	Adolescent	5805±25	4723-4558	SMP

					skeleton						
GrM-15943	PO 030	Pollera	MAL	PO 31 PE	Disarticulated/partial skeleton	Rossi 1885-1892	Tomba 13?	Adult	5775±25	4701-4548	SMP
GrM-13427	PO 031	Pollera	MSNF	PO 6690bis.3	Disarticulated/partial skeleton	Issel-Morelli 1892	Tomba 9?	Adult	5860±25	4794-4687	SMP
GrM-13435	PO 032	Pollera	MSNF	PO 6690bis.1	Disarticulated/partial skeleton	Issel-Morelli 1892	Undet.	Infans	5811±25	4726-4557	SMP
GrM-13501	PO 032	Pollera	MSNF	PO 6687.1	Disarticulated/partial skeleton	Issel-Morelli 1892	Tomba 3?	Infans	5851±25	4792-4620	SMP
GrM-19460	PO 033	Pollera	MSNF	PO 1 Morelli	Disarticulated/partial skeleton	Morelli 1885-1886	Tomba 1?	Infans	5860±50	4843-4585	SMP
GrM-13493	PO 034	Pollera	MSNF	PO 6677a	Disarticulated/partial skeleton	Issel-Morelli 1892	Tomba 2?	Infans	5901±25	4833-4716	SMP
GrM-13438	PO 034	Pollera	MSNF	PO_6677a (marked as PO_6677b)	Disarticulated/partial skeleton	Issel-Morelli 1892	Tomba 2?	Infans	5897±25	4830-4714	SMP
GrM-13498	PO 035	Pollera	MSNF	PO 6688.1	Disarticulated/partial skeleton	Issel-Morelli 1892	Tomba 4?	Infans	5870±25	4794-4692	SMP
GrM-13499	PO 036	Pollera	MSNF	PO 6690bis.2	Scattered/isolated/commingled remains	Issel-Morelli 1892	Undet.	Infans	5862±25	4792-4688	SMP
GrM-19290	PO 037	Pollera	MSNF	PO (prob) CrD/Poster2 Morelli (prob)	Disarticulated/partial skeleton	Morelli 1885-1886	Undet.	Infans	5855±25	4793-4624	SMP
GrM-13506	PO 040	Pollera	MSNF	PO 6682.1	Disarticulated/partial skeleton	Issel-Morelli 1892	Tomba 8?	Infans	5785±25	4707-4555	SMP
GrM-13514	PO 041	Pollera	MSNF	PO 6680.1	Disarticulated/partial skeleton	Issel-Morelli 1892	Tomba 7?	Infans	5904±25	4836-4717	SMP
GrM-13669 ³	PO 042	Pollera	MAL	PO 1 Issel-Morelli	Burial	Issel-Morelli 1892	Tomba 1	Adolescent	5839±25	4785-4616	SMP
GrM-14517 ³	PO 042	Pollera	MAL	PO 1 postcranium	Burial	Issel-Morelli 1892	Tomba 1?	Adolescent	5840±25	4786-4616	SMP
GrM-14489	PO 043	Pollera	MAL	PO T6246	Burial	Amerano 1890s	Undet.	Adult	5710±25	4650-4462	SMP
Lyon-14603	PO 044	Pollera	MAF	PO 1 Tiné	Burial	Tiné 1972	Tomba 1	Adult	5790±30	4712-4552	SMP
GrM-15912	PO 045	Pollera	MAF	PO INDET 25,II,26	Disarticulated/partial skeleton	Uncertain	Undet.	Adult	4050±25	2833-2487	Copper Age
GrM-15921	PO 046	Pollera	MAF	PO 25,I,12	Scattered/isolated/commingled remains	Gruppo Speleo Alassio 1981	Undet.	Adolescent	5810±30	4764-4553	SMP
Lyon-14607	STRAPA 001	Strapatente	MAF	STRAPA FRA 1	Burial	Franconi 1960s	Tomba 1	Infans	5630±30	4531-4369	SMP
Lyon-14608	STRAPA 002	Strapatente	MAF	STRAPA FRA 2	Burial	Franconi 1960s	Tomba 2	Infans	6075±30	5194-4854	SMP
Failed	ACN 002	Arene Candide	MAL	AC 6 PE	Burial	Perrando 1874	Tomba 3 Perrando	Adult			
Failed	ACN 028	Arene Candide	MAL	AC II BB	Burial	Bernabò Brea 1940-1950	Tomba II	Adult			
Failed	ACN 030	Arene Candide	MAL	AC IV BB	Burial	Bernabò Brea 1940-1950	Tomba IV	Adult			
Failed	BER 008	Bergeggi	MSNF	BER 1182 bag 01175 6903	Disarticulated/partial skeleton	Modigliani 1880	Undet.	Infans			
Failed	BER 009	Bergeggi	MSNF	BER 3573	Disarticulated/partial skeleton	Modigliani 1880	Undet.	Adult			
Failed	PO 029	Pollera	MAL	PO 32 PE	Burial	Rossi 1885-1892	Undet.	Adult			

1 ICC: Impresso-Cardial Complex (Binder and Sénépart, 2010; Arobba et al., 2017); SMP: Square Mouthed Pottery (Maggi, 1997a; Pearce, 2013); Chasséen (Maggi, 1997a; Crepaldi, 2001; Binder et al., 2008).

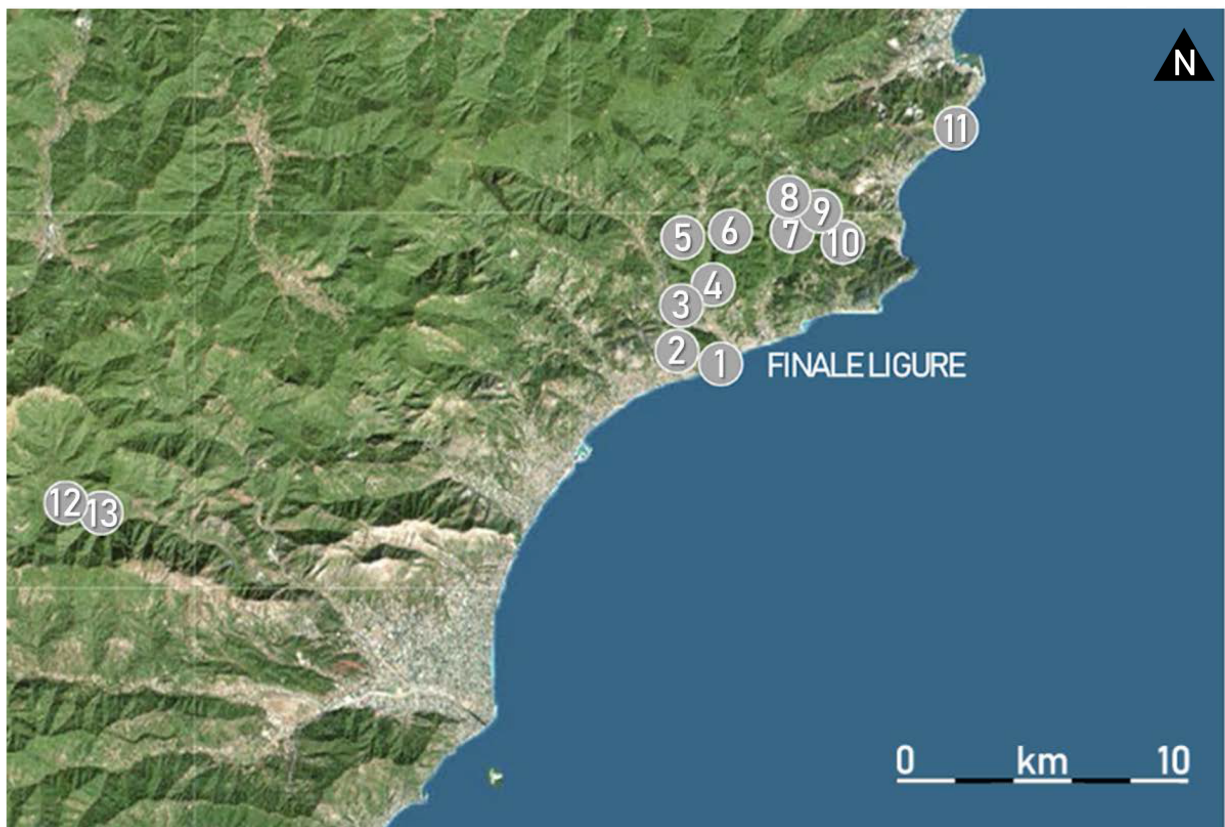
2 Remains from the same individual, PIP1 001, were divided in three boxes with different museum codes.

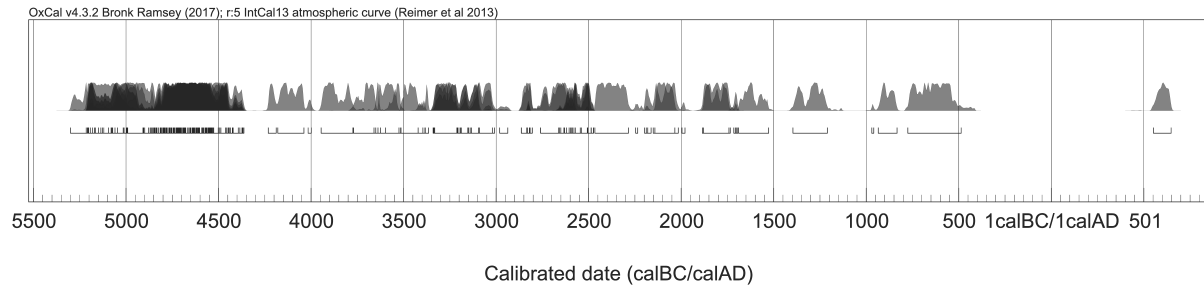
3 Same individual

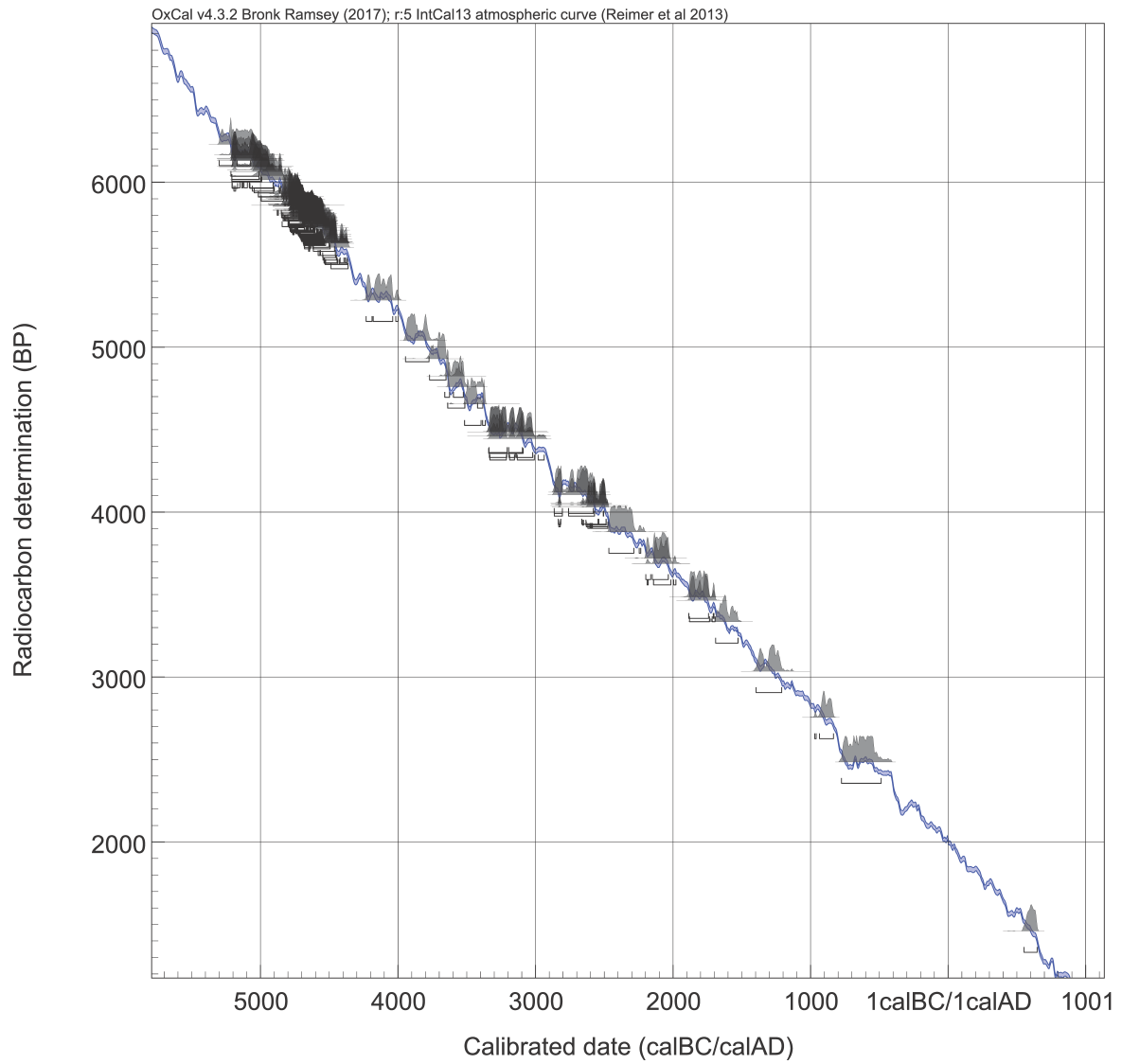
Figure 1 – Top: geographical position of Liguria and the Finalese area in northern Italy and the northwestern Mediterranean. Bottom: The location of the sites included in this study: 1) Arene Candide; 2) Battorezza, Mandurea, Parmorari; 3) Arma delle Anime; 4) Grotta dell'Acqua, Arma del Morto, Caverna della Matta o del Sanguineto; 5) Pollera; 6) Arma dell'Aquila; 7) Strapatente; 8) Boragni; 9) Pipistrelli; 10) Pian del Ciliegio; 11) Bergeggi; 12) Grotta delle Camere; 13) Arma di Nasino.

Figure 2 – Stack plot of the AMS dates for the 120 individuals included in this study. The ranges are 95.4% probability calibrated.

Figure 3 – Curve plot of the AMS dates for the 120 individuals included in this study. The ranges are 95.4% probability calibrated.







Declarations of interest: none

Vitale Sparacello, on behalf of the Authors of the manuscript